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ABSTRACT

This paper explores FM radio's struggle for survival in the 1940s, focusing primarily on the impact of Federal Communications Commission (FCC) decision making and on the influence and activities of the well-established radio corporations, primarily the Radio Corporation of America (RCA). It describes the invention of FM radio by Edwin H. Armstrong and his early demonstrations of it to RCA. The paper next explores some of the early FCC considerations on allocating unoccupied radio channels and notes the reaction of the AM radio industry and of those who were developing television in the 1930s. An FCC decision to allow commercial FM broadcasting is discussed, and then the paper considers post-World War II planning by the broadcast industry, including the industry's efforts to move the band on which FM could be broadcast and the effects that move had on FM radio and on television. The final FCC decision reallocating FM Channels is reported and a series of questions asked of the FCC by FM industry proponents and not responded to are appended. (TJ)

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A QUESTION OF INTERFERENCE:

FM RADIO'S EARLY STRUGGLE FOR SURVIVAL

1934 - 1945

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> It is not the cost, or the loss that those of us who have been developing this art (FM) have had to face; it is not the dollar loss; it is the loss of the ability to go ahead and do what you know is right, technically, to develop an invention to the service of the people of the country. We have lost that right. We are even enmeshed in regulations where the laws of nature are made up to fit the particular situation, and I cannot do engineering under those circumstances. I would not go through with the development of another invention myself so long as the powers that the Congress have delegated to the (Federal Communications) Commission are in existence under any circumstances.
>
> Edwin H. Armstrong, February 3, 1948[1]

As the twentieth century approached its fifth decade, two new broadcast technologies stood ready for commercial use: frequency modulation (FM) broadcasting and television. Both promised an abundance of new services, programs and technical performances to the American audience. Both posed a potential economic threat to the existing AM radio industry. Yet, each service was unique enough in its capabilities to allow the parallel development and acceptance of both technologies without a direct competitive confrontation.

Eight years and one World War later, television had taken a firm hold on the U.S. broadcasting industry, while FM manufacturers and broadcasters had been given a back seat -- and spectrum space -- to television and AM. One man's invention had clashed with the vested interests of big industry, not in the marketplace of free enterprise, but in the politics of regulation. FM's inventor Edwin H. Armstrong recounted its plight in hearings before the U.S. House of Representatives Interstate and Foreign Commerce Committee in 1945 (hereafter referred to as the 1948 House Hearings),[2] mourning the loss of the ability to develop an invention to the service of the people of the country.

The House Hearings, held to consider House Joint Resolution 78, relating to the assignment of a section of the 50 megacycle (mc) band of radio frequencies for frequency modulation, detailed the early years of FM broadcasting. The testimonies of Hearings witnesses, both FM supporters and opponents, suggested a timeline which became the point of departure for a chronological investigation of FM as a new technological innovation making its entry into the regulated world of the broadcasting industry. Further research revealed that, within the chronology, a documentation of the allocations and reallocations of various ultra-high-frequency spectrum bands to FM and television would provide a series of check points on the status of the two new broadcast technologies.

This paper explores FM's struggle for survival in the 1940's, focusing primarily on the impact of Federal Communications Commission (FCC) decision-making and on the influence and activities of the well-established radio corporations, primarily the Radio Corporation of America (RCA). While FM's relocation in the broadcasting spectrum was based ostensibly on concern about skywave interference raised during FCC frequency reallocation hearings in 1945, this study also suggests competition between FM and television on such issues as financial support, audiences and advertisers, patents and FCC favor.

FM's Beginnings

In the 1920's, four major problems plagued radio broadcasting. These were: (1) interruption of transmission by natural lightning or man-made static; (2) inability to transmit full musical range because of lack of channel space; (3) drastic mutual curtailment of service ranges of two stations on the same frequency, even when located hundreds of miles apart; and (4) distortion of reproduction at certain points due to selective side-band fading.[3]

The problem of static interference was the greatest problem of the art, and most engineers considered it to be insolvable. However, studies performed by Armstrong in 1924 suggested that static could be eliminated by producing a radio wave with different characteristics from the waves which produced the static, and then having a receiver which was immune to the ordinary waves and responsive only to the special waves. This special kind of wave became known as the wide band frequency modulated wave.

The wave differed from the amplitude modulated wave (used in standard broadcasting) as follows: modulation is a process of imparting sounds or other signals to the transmitted radio wave. Waves have two characteristics which define them--amplitude (intensity) and frequency. Amplitude modulation permits sound to control the intensity of the transmitted radio wave, while the frequency remains constant. Frequency modulation varies the frequency in accordance with the sound, with constant amplitude.[4]

Armstrong applied for four patents to cover his inventions in 1933. In 1933-34, he demonstrated his system to RCA President David Sarnoff, a close personal friend to whom he had sold the patent rights to his last invention, the superheterodyne, in 1923. Executives and engineers of RCA, with whom Armstrong had had a long professional relationship, also attended the demonstrations, first at Philosophy Hall at Columbia University, where Armstrong was professor of electrical engineering (December 1933), then on top of the Empire State Building, where the RCA transmitters were located (June 1934). Using a two-kilowatt antenna, Armstrong transmitted FM signals to a receiver at Westhampton Beach, Long Island, sixty-five miles from New York and nine hundred feet below the line of sight from the Empire State. The results surprised even Armstrong: "The excellence of the results obtained in the initial tests surpassed all expectations, perfectly quiet reception being secured through the heaviest thunderstorms when

all the standard broadcast services had been rendered utterly useless."[5] Later, the experimental receiver was moved to Haddonfield, N.J., eighty-five miles from New York City and one thousand miles below the line of sight, with comparable results.

The FM demonstrations from atop the Empire State Building had shown an improvement in the signal-to-noise ratio, elimination of static, ultra-high frequency transmission distance (which went beyond the horizon) and the absence of all effects of side-band fading. RCA engineers filed various reports on the system. C.M. Burrell of RCA Manufacturing found that fifty watts in the antenna of an FM transmitter produced a signal-to-noise ratio of the same value as a two kilowatt (two thousand watts) AM transmitter. Harold H. Beverage concluded after exhaustive measurements: "Frequency modulation with a deviation of one hundred kilocycles is shown as increasing the service radius from three to five times the AM service radius."[6] Having given RCA an exclusive preview of the FM system for almost two years, Armstrong hoped that the Corporation would go ahead and put the system into use.[7]

That, however, was not to be the case. When RCA showed no inclination to adopt and promote FM, Armstrong announced the system in the public press on April 26, 1935.[8] Not quite two weeks later, on May 6, 1935, RCA announced the start of a series of field tests to develop television, at a cost of one million dollars, without a mention of FM.[9] Armstrong saw RCA's action as an attempt to block the development of FM and the allocation of suitable radio channels to FM.[10] RCA reinforced that position by informing Armstrong that his equipment was to be removed from the Empire State to make way for the resumption of television experiments. Interestingly, the Corporation also requested that Armstrong turn over his equipment to its best engineers for further tests.[11]

The technical details of frequency modulated broadcasting were presented by their inventor at the November 1935 meeting of the Institute of Radio Engineers (IRE) in New York. At the conclusion of his paper,[12] Armstrong's audience of fellow engineers experienced a sequence of sounds transmitted by experimental FM station W2AG in Yonkers, seventeen miles away: water being poured, paper being crumpled and torn, an oriental gong, Sousa marches and piano solos. Unlike the distorted versions of those sounds transmitted via standard AM waves, the sounds were readily recognizable.[13]

The clarity and naturalness of the tone, however, were merely the surface of the FM revolution. Armstrong's system succeeded in (1) reducing static; (2) making high fidelity reception practical; (3) operating on less power while achieving greater efficiency than standard broadcasting transmitters; (4) recording a strong staticless range of one hundred miles (not the horizon-determined radius of a television signal), without selective fading; (5) enabling the same frequencies to be assigned to stations located in cities two hundred miles apart by eliminating signal interference;[14] and (6) providing a new medium for chain broadcasting as a replecement for telephone wires limited by narrow frequency bands.

While no one questioned the technical details of the system, skeptics nonetheless expressed their doubts. Even with the evidence clearly at hand, they claimed that transmitters were too complicated, receivers were too costly, ultra-high frequency waves were limited in range and stopped at the horizon, and that two hundred kilocycles of spectrum space instead of ten were required for a channel. In a newspaper interview shortly after the IRE conference, which he attended, Andrew Ring, Assistant Chief Engineer for the FCC, shared his reaction: FM was interesting theoretically, but impracticable; the receivers required too many tubes; the FCC had not made the ultra high frequency ranges commercial.[15] Thus, while the skeptics' arguments were without ground, the FCC's initial reaction

to the new medium was unfriendly. The FCC's first annual report to Congress for fiscal year 1935, which included a section on technical developments in radio prepared by FCC Chief Engineer C.B. Jolliffe, did not even mention FM by name.[16]

Early FCC Considerations -- 1936

In June 1936, the FCC invited industry representatives to provide information which would assist the Commission in best allocating unoccupied radio channels in the public interest. Only Armstrong and Paul A. DeMars, Chief Engineer of the Yankee Network, spoke on behalf of FM. RCA, represented by its president David Sarnoff and Chief Engineer C.B. Jolliffe, formerly of the FCC, did not mention FM at all, but stated that they were pleased to present to the Commission the information and experience of RCA, gained from its operations in radio, research, communications, broadcasting, manufacturing and sales.[17] Even though RCA was the only company in the industry to whom the full details of FM had been disclosed, its representatives chose not to include RCA's field engineering tests on the FM system, but rather to play up the readiness of television. Sarnoff believed strongly that the establishment of a new service -- the addition of sight to sound -- gave television priority over a mere improvement for the existing service of sound.[18]

As a result of the 1936 hearing, the FCC assigned a major part of the spectrum between 40-120 mc to experimental television; most of the remainder was for government purposes. The Commission allocated only five channels to experimental FM, mindful that each channel occupied twenty times the width of an ordinary AM station (200 kc versus 10 kc). They forgot, however, that unlike FM, the frequencies could be duplicated every two hundred miles without signal interference. But the allocations were established on a temporary basis only, on the theory that if one service developed faster than another, readjustments could be made.

In October 1937, the FCC announced that it would consider license applications for the 20-300 mc portion of the spectrum:

> The allocation of the ultra-high frequencies vitally affects several important broadcast services, namely: television, facsimile, relay, high frequency and experimental broadcast services ... The investigations and determinations of the Commission justify the statement that there does not appear to be any immediate outlook for the recognition of television service on a commercial basis.[19]

Nonetheless, television was assigned seven channels between 44-108 mc, plus an additional 12 channels from 156-300 mc. The band between 44-50 was designated as Channel One, for local programming.[20]

RCA's initial rejection of FM in 1935 convinced Armstrong that he would personally have to demonstrate FM's possibilities to the public. He applied for a high-power experimental license to begin construction of his own 40 mc station in Alpine, N.J., W2XMN. After an entire year of red tape at the FCC, Armstrong received the license shortly after the 1936 hearings. The station began operating on a regular basis in 1939, three hundred thousand dollars worth of proof that Armstrong's invention did work. During construction of the transmitter, Armstrong commissioned General Electric (GE) to build twenty-five FM receivers for further experiments at Alpine. Soon thereafter, GE requested a manufacturer's license from Armstrong, who received his first royalty check for his FM invention in December 1938. By early 1940, one hundred fifty applications for FM stations had been received by the FCC, which had no place to put them in the spectrum. Once GE had entered the FM market, RCA applied for its own experimental permit. The Corporation had been, it said, pondering the economic feasibility of the Armstrong system for the past five years.[21]

FM -- Developing "Interference" with AM

With a network of FM stations developing and all commercial manufacturers except RCA producing FM receivers, Armstrong was enthusiastically predicting the

triumph of FM in the broadcasting industry: "With the cost of transmitting equipment for the new system already below the cost of the equipment for the standard broadcast type (for the same power output) and with the cost of broadcast receivers approaching levels that will permit large scale production and distribution, tne conclusion is likewise inescapable that within the next five years the existing broadcasting system will be largely superseded."[22]

Unfortunately, he overlooked the financial liability an FM changeover presented to the radio industry in terms of capital expenditure and technical reorganization. Investments in AM transmission and equipment were approximately seventy-five million dollars, with additional funds committed to research and the development of AM.[23] A complete switch in transmission methods would make nearly forty million radio receivers obsolete. FM, with its ability to provide simple network relays, loomed as a serious menace to the established AM network oligopoly (the National Broadcasting Company, Inc. (NBC), the Columbia Broadcasting System, Inc. (CBS), and the Mutual Broadcasting System, Inc. (MBS)) by making available as many high-powered FM stations as the U.S. economy could support. It threatened to fragment large mass audiences into small interest groups listening to a diversity of available programs, reducing the size of the audience which a station could sell to advertisers. An investment in FM development would also mean a drain on AM profits -- which major radio manufacturers had earmarked to support the early years of television growth. Finally, RCA would never be content to own a manufacturing permit for FM, but would want to buy the patent outright.

Still, large sectors of finance and industry wished FM well. Fortune magazine closed a 1939 story on Armstrong and the radio revolution with strong words to the FCC:

> While the duty of the FCC, in making short-wave band allocations was clearly to get television on the air as quickly as possible (the British having already beat the U.S. by a couple of years), the Commission's failure to understand frequency modulation, and to place a proper estimate on its technological importance, is just as deplorable as the industry's failure to push it. Instead of encouraging substantial capital outlays, which the development of this invention would cause, the Commission acted as a deterrent by relegating Major Armstrong to an experimental corner of the ultrashort wave spectrum. What FM needs at the present time above all things is an allocation that will put it on a commercial status and will at the same time be large enough to permit it to operate to full advantage.[24]

Television was, at this same time, approaching its commercial beginning. On April 30, 1939, RCA's Sarnoff demonstrated to the public the capabilities of television at the grand opening of the World's Fair in New York City. That year, the FCC granted television limited commercial status (the stations could not sell time to advertisers), for the sake of further experimentation and testing in engineering and programming, without adopting uniform standards. A report by the Television Committee of the FCC on November 15, 1939, stated that television had not yet advanced beyond the experimental stage.[25]

While claiming that the public was "tickled to death" with the American system of broadcasting and that "we are giving the public everything we know how to give them today,"[26] AM radio executives applied for FM licenses as insurance policies against further technical developments. At first the FCC required joint AM/FM owners, who were prone to broadcast the same programming on both stations, to devote two hours a day on FM to new and original programs in order to show FM's ability for diverse programming. However, faced by the strenuous opposition of a virtually united front of the radio industry, the FCC reversed its original judgment and required no separate FM programming.[27]

Whether for different programming options or just the novelty of the invention, the public purchased FM receivers. By 1940, five hundred thousand receivers were tuned to fifty commercial FM stations. The rapid growth of FM prompted the FCC to consider allocating even more spectrum space for the wide-band signals.

Commercial Designation by the FCC

In January 1940, the Commission held a hearing to consider a request by RCA that the temporary 44-108 mc television frequency allocations of 1937 be made permanent. In the course of the testimony, Chairman Lawrence Fly discovered that RCA had failed to disclose its reports on FM at the 1936 hearings. He immediately postponed discussion on permanent television assignments and scheduled a further hearing on FM needs for additional channels. During the six weeks before the second hearing was held, RCA launched a massive campaign to sell television receivers with Channel One (44-55 mc), a logical place for FM to expand. Television had been so heavily publicized and so long delayed that such a sales campaign might have resulted in strong pressure to adopt the standards and spectrum assignments of the company selling the most sets.[28] When the FCC became aware of RCA's tactic to keep FM contained and to accelerate the growth of television, it relegated television back to experimental status.

The frequency hearings were finally held in March 1940. Despite suggestions by RCA that a narrower channel width be used for FM, which would have necessitated rebuilding the entire system, and recommendations by CBS that the channels in dispute be given to television,[29] the Commission took the 44-50 mc band width from television and assigned it to commercial FM, "... finding that high frequency broadcasting using frequency modulation had developed to a stage where regular service could safely be inaugurated."[30] Five channels were set aside for educational use (42-43 mc), while the remaining thirty-five were designated for commercial use. The displaced television Channel One was moved to a government band at 60-66 mc.

The FCC also held hearings in January and April, 1940, regarding television, which revealed that the industry was at odds as to transmission standards and the readiness for commercialization. Standardization too early might freeze

technical developments before they had reached their optimum point. An industry-organized National Television Standards Committee submitted a report to the Commission on January 27, 1941; on April 30 of that year, the FCC restored television's commercial status and ruled that television must use frequency modulation to transmit its sound.

Post-War Planning

The war put a halt to commercial production of both transmitters and receivers for FM and television, as the industry shifted its output to meet military needs. FM was used extensively for short range communication on the battlefields and seas, while communications demands encouraged the development of technology which would enhance the radio and television industries after the war.

Anticipating the rapid growth of FM broadcasting after the war, in September 1943 the FCC recommended to the industry the establishment of a Radio Technical Planning Board (RTPB) to give advice and make recommendations as to standards and frequency allocations for various classes of service. The Board was sponsored by nine major industry associations, including the IRE, the National Association of Broadcasters (NAB), the Radio Manufactureres Association (RMA), FM Broadcasters, Inc. (FMBI) and others. Its chairman was Dr. W.R.F. Baker, vice president of GE.

Panel 5 of the Board, composed of men who built the FM industry, dealt with FM problems. The most serious issue which the Panel considered, raised by representatives of NBC and CBS, was the possibility of serious ionosopheric or skywave transmission disturbances in the existing FM band which might dictate a shift to higher frequencies. The Panel considered the interference problem carefully, consulting the U.S. government authority on the propagation of radio waves, Dr. J.H. Dellinger, Chief of the Radio Section of the U.S. Bureau of Standards and Chief of the Interactive Radio Propagation Laboratory of the U.S. Government.

Dellinger reported to the Panel that the fears of disturbance in the lower band were not well founded, that no part of the spectrum was utopian, and that no frequencies were absolutely free from transmission vagaries.[31]

As a result, Panel 5 voted 27-1[32] to recommend that the existing FM allocations be maintained and that the band be expanded upward into the band above 50 mc, then allocated to television. Panel 6 of the Board, which dealt with television, concurred. In addition, Panel 2 on frequency allocations recommended that seventy-five channels be allocated to FM from 43-58 mc and television be assigned to 60-102, with experimental bands from 460-956 mc.

The industry's combined recommendations for postwar allocations were submitted to the FCC in a hearing held September 28 to November 2, 1944,[33] which generated 4559 pages of testimony, 543 exhibits and 231 witnesses. There was little doubt that the industry's recommendation for spectrum reallocation would be accepted. However, three days before the hearings ended, a surprise witness for the Commission, K.A. Norton, a former FCC Assistant Chief Engineer who was on war time loan to the Signal Corps, offered his theory of skywave interference. He believed that "sporadic E" and "F2 layer" interference would plague FM in the next few years at its existing frequency as the sunspot maximum approached. Much of Norton's testimony was delivered in a closed hearing due to the alleged classified nature of the material.

Norton forecast serious interference in the lower FM band through F2 layer transmission[34] at the peak of the next sunspot cycle, based on a theoretical interpretation of regular ionospheric measurements at the National Bureau of Standards. According to his theory, tropospheric phenomena increase in importance as the frequency of transmission is increased (the situation proposed for FM), but he placed greater emphasis on the possible detrimental effects of skywave phenomena at the lower frequencies. It was his conclusion that FM should be

moved upward in the radio spectrum.[35]

Norton's testimony immediately caused a stir in the radio industry. Four days after the close of the hearings, H.H. Beverage, vice-president of RCA Communications (RCAC) and associate director of research for RCA Laboratories, told Broadcasting magazine: "The data upon which these estimates are based are a startling departure from the ionospheric conditions observed in Washington."[36]

On January 16, 1945, the Commission proposed a tentative reallocation plan in a 265 page report.[37] FM would be moved from the 50 mc band with forty channels to the band at 84-102 mc with ninety channels (twenty for educational use, seventy for commercial). Television would retain twelve six-megacycle channels between 44-210 mc (44-84; 180-216), with most visual service above 480 mc "where high definition color would be possible."[38] FCC Chairman Paul Porter, formerly with CBS during the previous allocation discussions in 1940, felt the "intolerable interference" mandated moving FM to a region free from skywave interference, outweighing the economic inconvenience the relocation would cause. "Public interest requires that FM be established in a permanent place in the radio spectrum before a considerable investment is made by the listening public in receiving sets and by broadcasters in transmitting equipment."[39] The report pleased almost no one in the midst of conflicts between FM and television for the 50 mc area, and debates between "upstairs" and "downstairs" television advocates.

CBS, which favored all television assignments above 480 mc or "upstairs," interpreted the facts as stripping "downstairs" advocates (who wanted assignments around 50 mc to be made permanent) of the hope that television would remain at that level. At the same time, it bemoaned the exclusive assignment of one low frequency channel to television since it was done with the thought that FM might eventually take it over.[40] The FM Broadcasters, Inc., called an emergency meeting three days after the plan's announcement to draft an official position: "While

the Board expressed its unanimous approval to that part of the report allocating additional frequencies for FM broadcasting and maintenance of high fidelity standards, it expressed concern over changing from a band where FM has been operating satisfactorily for more than five years to one which has been unexplored for this type of service and for which receiving sets and transmitters have to date not been contemplated nor designed."[41] Zenith proposed that the suggested change would cancel out most of the radio industry's experience in FM, wipe out the existing listeners necessary for commercial broadcasting and delay FM's expansion by at least one year, probably longer.[42]

Hearings to consider the reallocation plan began on February 28, 1945. A number of briefs were filed for the Commission's consideration. NBC-RCA-RCAC termed the FCC proposals generally sound, but objected to some assignments for FM: "The immediate needs of television should have priority over possible future needs of FM."[43] CBS supported the FM move with the interference argument.[44] Cowles Broadcasting supported the proposal, expressing fears that rivalry between AM and FM was not commercially nor financially feasible.[45] The NAB felt the allocation dealt justly with broadcasting in terms of total available space, while neither endorsing nor opposing the FM allocation.[46]

Opposition to the plan centered on the validity of Norton's initial testimony in 1944 and the Commission's acceptance of his evidence over that of other experts. FMBI charged that the Commission rested its proposal for the shift almost entirely on the testimony of Norton and rejected the testimony of such widely experienced propagation experts as Dellinger, Beverage and Armstrong.[47] WCBA, Schenectady, objected to the Commission's apparent disregard of the recommendations they had solicited from the industry.[48] The Yankee Network contended that the plan would work great injury upon the public and existing FM licensees, and would unnecessarily inflict injury and impose a disadvantage on FM pioneers, while giving benefit and

advantage to latecomers.[49] Armstrong challenged Norton's calculations on propagation, supporting his challenge with a memorandum by himself, Beverage and Charles R. Burrows, based on studies done in collaboration with Dr. G.W. Pickard, Dr. H.T. Stetson and Stuart Bailey, all widely known engineers.[50]

RTPB's Panel 5 charged that the Commission's proposed findings did not give "due consideration" to Panel 5's study and recommendations. They argued that the two exhibits on which Norton based his conclusions were not entirely factual but involved interpretations and conclusions, instead of basic data: "It is unfortunate that, throughout the entire range of frequencies extending from 40-110 mc, data with respect to all the phenomena of importance are not only meager, but the interpretations which must be made to express the results in terms of interference and service areas are extremely complicated, frequently requiring assumptions of unproven validity and not easily understood by those who have not devoted years of study to the subject."[51] The Panel expressed disbelief that the Commission's choice, as far as it was influenced by propagation phenomena, was primarily between the conclusions of Norton on the one hand and those of Dellinger and Beverage on the other.[52]

The propagation debate was carried on at the 1945 IRE Convention in a paper submitted by Norton and E.W. Allen of the FCC's Technical Information Division. The paper contained a large portion of the technical evidence which formed the basis for the FCC's relocation of FM. Outstanding FM experts attacked the validity of Norton's conclusions for the FM move in a reaction session,[53] but Norton never used the opportunity to defend his theories. Under cross-examination at the 1945 hearing, charged with the error in his principal prediction with the words "But you were strong" admitted: "Oh, certainly. I think that can happen frequently to people who make predictions on the basis of insufficient information. It happens every day."[54]

During a secret conference of military and industrial engineers to consider the battle over the F2 layer (March 12-13), Dellinger explained why Norton's conclusions were different from his:

> The reason is because, implicitly if not explicitly, of a very considerable exaggeration of the effect of ionospheric interference. Ionospheric interference is very little at either 50 or 100 mc... So that the elaborate demonstrations that it is many times less at 100 mc than at 50 mc is pointless.[55]

Armstrong objected most to Norton's reliance on theory without any experimental checks:

> The variables involved are so many that the abandonment of the time-honored approach of at least "listening to the signals" and its replacement by the approach of the "armchair geographer" is an incredible thing. It is more incredible that anyone should have paid any attention to it, and with this statement, we could ordinarily let the matter rest.[56]

Zenith Radio Corporation conducted propagation studies with the FCC in 1945. Having known for fifteen years that the fading exists in frequencies greater than 30 mc for receiving points beyond the horizon, and that interference increases with frequency, they measured FM signal reception at 84 and 107 mc at a distance of 70 miles from the transmitter. Changing FM's position in the spectrum, on the basis of interference considerations was not justified according to their results: "Actually, as we now know, in going to the new frequency modulation band we have merely exchanged long-distance interference, which exists for only several months out of the year, for the much worse interference due to fading which exists practically every day.[57]

The hearings also gathered data on the economic effects which the move would have on the radio industry and on the popularity of the medium. The FCC's Economic Division surveyed 101 FM manufacturing plants to determine the number and retail value of existing FM receivers. Of the almost four hundred thousand receivers manufactured at a value of seventy-six million dollars, only fourteen thousand were FM only ($3.3 million); the rest were combined AM/FM, which meant

that they would not become obsolete as a result of the shift.[58] A Sylvania survey showed that 91.3 percent of the sample wanted FM; that 70.0 were willing to pay five dollars more per set; 25.0 percent would pay fifteen dollars more and 16.5 percent would be willing to pay an additional thirty dollars for an FM receiver. The RTPB computed the cost of an FM receiver for the 84 mc band to be four to thirty dollars more than at 44 mc.[59]

As late as May 14, 1945, the Commission had still made no decision on the permanence of the allocation plan. The Engineering Division of the FCC wanted FM to be allocated to 84-102 mc as proposed in January; the Commission itself wanted FM to be assigned to 60-80 or 60-100 mc. On May 17, 1945, the FCC allocated all parts of the spectrum above 25 mc except 44-108 mc, which affected FM and low definition television. The Commission called for engineering tests to be run by top propagation experts[60] during the summer of 1945, a season of high sunspot activity and sporadic E transmission. The Commissioners were fairly confident that their delay in allocating the spectrum would not affect the future development of service because the War Production Board predicted the radio industry would not resume production of transmitters "in 1945 or even in the first part of 1946 unless Japan capitulated."[61]

The Final Allocation Report

A final allocation report was issued on May 25, 1945, without permanent allocations for FM and television. According to the FCC, FM was expected to become the "finest aural broadcast service attainable in the present state of the radio art."[62] The report devoted some fifty pages and two appendices to an examination of all possible types of interference in FM -- ionospheric, tropospheric, F2 layer, sporadic E layer. It cited ionospheric or skywave interference as the reason for moving FM from its low band, but recognized that tropospheric interference increased higher up. All information in the appendices

was applied to both FM and television, since they are governed by the same laws of radio propagation. But the report itself devoted only four pages to television, without any mention of interference.

As events of the war took their course, the War Production Board told the Commission that it might permit civilian manufacturing to resume sooner than anticipated. The FCC asked for more oral arguments on June 22 and on June 27 made its decision, before the summer propagation studies could be completed: FM would be assigned to the 92-106 mc band, a better location for sporadic E effects. Television was assigned to the 44 mc band, a turn of events which was doubly ironic. First, it was an accepted fact that television was perhaps twenty-five times more vulnerable to atmospheric disturbances than FM. Second, according to the 1936 allocations, television's "downstairs" location was to be a temporary assignment, since television was more suited to the ultra-high frequencies.

Power standards were also established for FM stations, which reduced the power of mountain top transmitters to a few percent of their original outputs. Armstrong's Alpine station was cut from 50 kilowatts to 1.2, which limited its ability to transmit to New York City. Stations which had been able to give service up to 150 miles were restricted to ranges of 40-50 miles covering one-tenth the area. The plan under which this reduction of power was carried out was called the "Single Market Plan," originally suggested by a former vice-president of CBS. Under the plan, a large number of stations would be required to cover the area one high-powered station would cover, ideal for advertisers and broadcast chains, but not necessarily for the listeners to whom FM offered the opportunity for a diversity of programming supplied by FM networks.

Even as the FM industry attempted to make the transition from one band to the other, the FCC hindered them. Since no "new" receivers were available in

1945, the shift would have put FM broadcasters in the position of playing to an empty house. To remedy this problem, manufacturers proposed to bridge the gap between production and use by building FM sets which would receive both bands. The FCC forbade such a move, and threatened to cut off transmission if the manufacturers defied the ban.[63]

FM proponents questioned the reasons behind the FCC's decision, but never received an answer. E.F. McDonald of Zenith addressed thirteen questions to FCC Chairman Paul Porter in 1946, and had still not received an answer at the time of the House Hearings in 1948.[64] (See Appendix) In 1948, legislators anxious to restore FM service to rural areas no longer served by the low power FM stations in cities attempted to have Congress legislate FM's return to the 50 mc band. That effort failed as the House Committee became wary of stepping into the regulatory agency's domain.[65]

Armstrong resigned himself to the decision: "The allocation has been handed down. Now it's up to all of us to do everything we can to have a service ready for the people at the earliest possible moment."[66]

The FM industry did respond to the challenge and in eighteen months had FM in the high band. After an initial rise in receiver sales and station applications, FM's struggle began to show as applications withered and some construction permits were returned, while television expanded. In 1949, the FCC noted "a sudden surge in television applications and a leveling off of FM requests."[67] The situation was worse in 1950, when the FCC concluded the decline "... was largely due to economic problems and uncertainties occasioned by the rapid growth of television and the limited number of satisfactory FM receivers which have been purchased and placed in use."[68]

It was not until the 1950's and early 1960's, with the development of FM stereo, that FM experienced the growth and development that had been predicted

for it during the 1940's. Symbolically, in 1965 thirty-two FM antennas were installed on top of the Empire State Building.

Postscript

Armstrong continued to fight for use of the 40 mc band for regional stations and inter-city relays, the topic of the 1948 House Hearings. Further, he decided in 1948 to fight RCA and other corporations who began installing FM sets without a limiter and without a license under Armstrong's patents. On July 22, he brought suit against RCA and NBC on charges of willfully infringing, and inducing others to infringe, five of the basic patent rights.[70] The litigation dragged on for almost six years, due to grueling cross-examination by RCA attorneys, draining both Armstrong's physical and financial resources.

Sarnoff protected the corporate position of RCA throughout the trial, explaining RCA's role in the discovery and development of FM: "I will go further and I will say that RCA and NBC have done more to develop FM than anybody in this country, including Armstrong."[71]

The battle between the giant corporation and the single inventor proved to be too great for Armstrong. In fact, RCA's tactic had been to discredit Armstrong as an inventor, not only of FM, but of the regenerative circuit as well. A broken, defeated man, Armstrong walked out of a thirteen-story window on January 31, 1954, the end of a struggle to make his static-free invention live.

Conclusion

This paper has traced the early history of frequency modulation broadcasting in the United States, chronicling the delay and near death of an important technical innovation caused by an FCC decision based on questionable technical evidence. It has discovered again the silence, broken only by speculation, which surrounded McDonald's unanswered questions to the FCC regarding the 1945 spectrum

reallocations. An attempt has been made to explore the clash of FM, one man's invention, with television, an innovation backed heavily by traditional broadcasting interests, in a marketplace ruled not by the economics of free competition but by the maneuvers of pressure groups to influence the regulation of scare resources and technical standards.

There is little doubt that television would have assumed its dominant position in the broadcast industry regardless of the existence or non-existence of FM. Its novelty, immediacy, ability to carry visual as well as audio signals, in addition to the vested interest and support of the established radio industry, all but guaranteed its success. Still, television proponents seemed to perceive FM not as an innovation which could develop in parallel along with television, but as a direct competitive threat to its existence. The result was a not always subtle economic and social attack against FM, which influenced the industry's once-and-future colleagues sitting as Commissioners on the FCC. The existence and extent of this industry pressure need to be documented by further research.

What actually prompted the FCC, a panel of laywers, not engineers, to reject the testimony of leading radio industry propagation experts in favor of a Signal Corps Engineer, is still not clear. The Commission functioned with an underpaid technical staff which relied heavily on broadcast industry engineers for help. What is clear is that the FM shift upward in the spectrum, a move which made all FM receivers and transmitters obsolete, delayed the rapid expansion of FM predicted by most industry experts.

Television assumed FM's place (spectrally and otherwise) as a new invention greeted with enthusiasm by the post-war economy and society. Television also continued to have a favored place in the hearts -- and ears -- of the FCC, whose decision to shift the FM band, based ostensibly only on technical grounds, was made "in the best interest of FM broadcasting." Thus FM's inability to do little

more than to survive its first entry into the broadcast arena must be attributed to more than the question of technical interference and the economic clash with AM radio and television. The static-free transmission system of FM was unable to clear a path from its inventors, relative newcomers to the broadcast industry, to the FCC Commissioners through the static of well-established broadcasting interests. FM's early struggle to survive was definitely a question of interference.

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APPENDIX

Excerpts from a letter to Paul A. Porter, Chairman, FCC, from E.F. McDonald, Jr., Zenith Radio Corporation[64]

February 1, 1946

... it would help me in arriving at my own conclusions if you would give me your answers to the thirteen questions that follow:

First question: Who was it who first suggested to the Commission that it take away from FM the 50 megacycle band, where it had rendered an unequaled service in many areas for five years, and move it to the untried, unexplored, unproved 100-megacycle band, which, as has now been demonstrated, will make it primarily a city service?

Second question: Why was the proposal to move FM from the efficient 50-megacycle band to the inefficient 100-megacycle band advanced only after FM had proved its superiority to standard AM broadcasting?

Third question: Why did the Commissioners ignore the advice of the very Radio Technical Planning Board that had been organized at their request?

Fourth question: Why did the FCC again ignore the advice of the Radio Technical Planning Board which, after hearing the testimony presented at the FCC hearings, voted so overwhelmingly against moving FM?

Fifth question: Why did the Commission accept the advice of theorist Norton and ignore the recommendation of seven distinguished propagation experts?

Sixth question: Why did the Commission move this great service from the proved, efficient 50-megacycle band to the untried and unproved 100-megacycle band, against the evidence of the only factual data available, and before itself making actual, comprehensive tests of the new frequencies?

Seventh question: Why did the FCC assign television to the 50-megacycle band when it knew that television was far more subject to interference than FM?

Eighth question: Why did the Commission state in its press release that their Laurel findings disproved our findings when it was obvious that they did not, instead of revealing to the public that their long-range Andalusia tests confirmed our findings?

Ninth question: Why, Chairman Porter, did you ask me to include the 42-44 megacycle band in our petition, which inclusion brought in objections from various police departments all over the country who had been assigned that band, and from others, after we had indicated our belief that publi. interest would be served at this time by the reassignment of only the 44-50 megacycle band?

Tenth question: Why did the Commission ignore the uncontroverted factual evidence established by your tests, and ours, and deny the prayer of the petition which we filed at your personal request?

Eleventh question: Why did the Commission again ignore the testimony of the distinguished scientists who, as above stated, confirmed our findings?

Twelfth question: Was any weight given by the Commission to testimony of private manufacturers who were tooled to produce single-band 100-megacycle sets, and did not wish to redesign their sets?

Thirteenth question: Is it the Commission's intention to permit stations now broadcasting on the 50-megacycle band, and interfering with no other service, to continue on this band long enough for further comparative, Nation-wide, comprehensive testing with new stations on high power on the 100-megacycle band, or do you intend to remove them from the air and forever destroy their opportunity to further demonstrate to the entire radio engineering fraternity and to the public, the much greater efficiency of the 50-megacycle band for providing service to the farmer?

Answers to the above questions, or to any of them, will be greatly appreciated

Sincerely,

E.F. McDonald, Jr.

NOTES

1 Statement of Dr. Edwin H. Armstrong in Hearings before the House Inter-State and Foreign Commerce Committee on H.J. Resolution 78, 80th Cong., 2d sess., pt. 1 at 19 (February 3-4, 1948).

2 Hearings before the House Interstate and Foreign Commerce Committee on H.J. Resolution 78 (A Joint Resolution Relating to Assignment of a Section of the 50-Megacycle Band of Radio Frequencies for Frequency Modulation (FM)),80th Cong., 2d sess., pt. 1 and 2 (February 3-4, March 31 and April 1, 1948). Hereafter cited as "1948 House Hearings."

3 Edwin H. Armstrong, "Evolution of Frequency Modulation," Electrical Engineering 59 (December 1940): 485.

4 Federal Communications Commission, Sixth Annual Report, (Washington, D.C.: U.S. Government Printing Office, 1941), p. 66.

Amplitude refers to the height of a particular wave; frequency is related to the length, or distance, covered by one wave. It is expressed in units of cycles per second.

5 Armstrong, "Evolution of FM," p. 488.

6 Edwin H. Armstrong, "A Method of Reducing Disturbances in Radio Signalling by a System of Frequency Modulation," Proceedings of the Institute of Radio Engineers 24 (May 1936): 720.

7 Armstrong, 1948 House Hearings, p. 7.

8 "Radio Invention Helps End Static," New York Times, April 26, 1935, p. 21.

9 David Sarnoff, Statement delivered at Annual Meeting of RCA Stockholders, New York City, May 7, 1935 quoted in David Sarnoff, Pioneering in Television: Prophecy and Fulfillment (New York: Department of Information, Radio Corporation of America, 1946) pp. 21-24.

10 Armstrong, 1948 House Hearings, p. 7.

11 Ibid.

[12] Armstrong, "A Method of Reducing Disturbances," pp. 689-740.

[13] "System's Advantage Is 'A Discrimination Against Noise,'" Electronics, June 1935, p. 27.

[14] Until this time, two powerful stations (AM) could not be placed on the same wavelength (frequency) within one thousand miles or more of each other without interference.

[15] Armstrong, 1948 House Hearings, p. 8.

[16] Federal Communications Commission, First Annual Report to the Congress of the United States for Fiscal Year 1935, (Washington, D.C.: U.S. Government Printing Office, 1936), pp. 27-28.

The report stated that very high frequencies above 30 mc were capable of serving only a small area, and, as such, offered a means of supplying strictly local service to any numbers of population centers.

[17] Armstrong, 1948 House Hearings, p. 9.

[18] Eugene Lyons, David Sarnoff (New York: Harper & Row, 1966), p. 213.

[19] Federal Communications Commission, Press Release #23463, October 13, 1937 cited by Waldrop and Borkin, pp. 70-71.

[20] FCC Docket 3929, October 13, 1937, cited in a telephone interview with Julian Dixon, Chief of Research and Standards Division in the Office of the Chief Engineer, Federal Communications Commission, March 13, 1978.

[21] "Revolution in Radio," Fortune, October 1939, p. 121.

[22] Armstrong, "Evolution of FM," p. 493.

[23] "Revolution in Radio," p. 87.

[24] Ibid., p. 121.

[25] Federal Communications Commission, Sixth Annual Report, p. 65.

26 Lenox R. Lohr, NBC President, quoted in Charles Siepmann, Radio's Second Chance (Boston: Little, Brown and Company, 1946), p. 244.

27 Siepmann, p. 246.

28 Sydney W. Head, Broadcasting in America, 2d ed. (New York: Houghton Mifflin Company, 1972), p. 192.

29 Paul Porter, legal counsel for CBS, who became Chairman of the FCC in 1944, stated that "if there is a conflict, as there appears to be in the allocation problem with respect to television and FM, it is the opinion of CBS that preference should be given to the new public service of television rather than an additional system of aural broadcasting." Cited in Edwin G. Krasnow and Lawrence D. Longley, The Politics of Broadcast Regulation (New York: St. Martin's Press, 1973), p. 95.

30 Federal Communications Commission, Sixth Annual Report, p. 65.

31 J.H. Dellinger, "Response to 'Very-High Frequency and Ultra-High Frequency Signal Ranges as Limited by Noise and Co-Channel Interference,'" Proceedings of the Institute of Radio Engineers 35 (February 1947): 137.

32 The dissenting vote was cast by T.T. Goldsmith of Dumont Laboratories. See 1948 House Hearings, p. 99.

33 Federal Communications Commission, Docket 6651, "Allocation of Frequencies to the Various Classes of Non-Government Services in the Radio Spectrum from 10 Kilocycles to 30,000,000 Kilocycles," September 28 - November 2, 1944.

34 F2 layer transmission is brought about by the reflection of the transmitted wave from one of the electrified strata of the upper atmosphere. The ability of the F2 layer to reflect transmitted waves back to earth changes with the time of day, the time of year, the eleven-year sunspot cycle, and the frequency of the waves transmitted. It is only during the three peak years of the sunspot maximum, during winter months of those years, and during certain daylight hours (middle of the day) that the layer is in a condition where its effects can be of any importance in connection with FM broadcasting. See statement of C.M. Jansky, Jr., 1948 House Hearings, p. 90.

35 Brief on Behalf of Panel 5 "FM Broadcasting" of the Radio Technical Planning Board, FCC Docket 6651, February 21, 1945, cited in statement of C.M. Jansky, Jr., 1948 House Hearings, p. 108.

36 "Norton Urges FM over 120 mc, TV 500-1500 mc Band," Broadcasting, November 6, 1944, p. 23.

37 Members of the Commission at the time were Chairman Paul Porter, formerly a CBS attorney; Commissioner and former Chairman Charles Denny, former general counsel for the FCC, who later worked for NBC; Commissioner E.K. Jett, former FCC Chief Engineer, and Commissioner Ray C. Wakefield.

38 "Allocation Proposals Announced by FCC," Broadcasting, January 16, 1945, p. 13.

39 Federal Communications Commission, "Statement on FM Broadcast Service," in Docket 6651, January 15, 1945. Reprinted in Broadcasting, January 16, 1945, p. 17.

40 Paul W. Kesten, "Reaction to FCC Spectrum Plan," Broadcasting, January 22, 1945, p. 59.

41 "Reaction Varies to Allocation Proposals," Broadcasting, January 22, 1945, p. 16.

42 "McDonald Says FCC Proposal Would Delay FM Expansion," Broadcasting, February 5, 1945, p. 15.

43 National Broadcasting Company-Radio Corporation of America-Radio Corporation of America Communications, Brief filed in FCC Allocation Hearing in Docket 6651. Summarized in Broadcasting, February 26, 1945, p. 60.

44 Columbia Broadcasting System, Inc., Brief filed in FCC Allocation Hearing in Docket 6651. Summarized in Broadcasting, February 26, 1945, p. 60.

45 Cowles Broadcasting Company, Brief filed in FCC Allocation Hearing in Docket 6651. Summarized in Broadcasting, February 26, 1945, p. 60.

46 National Association of Broadcasters, Brief filed in FCC Allocation Hearings in Docket 6651. Summarized in Broadcasting, February 26, 1945, p. 60.

47 FM Broadcasters, Inc., Brief Filed in FCC Allocation Hearing in Docket 6651. Summarized in Broadcasting, February 26, 1945, p. 60.

48 WCBA, Schenectady, Brief Filed in FCC Allocation Hearing in Docket 6651. Summarized in Broadcasting, February 26, 1945, p. 60.

49
The Yankee Network, Brief Filed in FCC Allocation Hearing in Docket 6651. Summarized in Broadcasting, February 26, 1945, p. 61.

50
Edwin H. Armstrong, Brief Filed in FCC Allocation Hearing in Docket 6651. Summarized in Broadcasting, February 26, 1945, p. 60.

51
C.M. Janksy, Jr., Proceedings of the Institute of Radio Engineers 35 (February 1947): 137.

52
Panel 5, Radio Technical Planning Board, Brief Filed in FCC Allocation Hearing in Docket 6651. Summarized in Broadcasting, February 26, 1945, p. 61.

53
Edward W. Allen, Jr., "Very High Frequency and Ultra-High Frequency Signal Ranges as Limited by Noise and Co-Channel Interference," Proceedings of the Institute of Radio Engineers 35 (February 1947): 128-152. Respondents to the paper included C.M. Janksy, Jr., J.H. Dellinger, E.H. Armstrong, C.W. Carnahan, J.E. Brown, Paul A. DeMars, Dale Pollack and E.W. Allen, Jr.

54
Armstrong, 1948 House Hearings, p. 13.

55
J.H. Dellinger, Proceedings of the Institute of Radio Engineers 35 (February 1947): 137.

56
Edwin H. Armstrong, Proceedings of the Institute of Radio Engineers 35 (February 1947): 139.

57
C.W. Carnahan and J.E. Brown, Proceedings of the Institute of Radio Engineers 35 (February 1947): 140.

58
"Military to Confide Secret Data to Radio," Broadcasting, March 5, 1945, p. 64.

59
"All Allocations by May 1 Is FCC Goal," Broadcasting, March 12, 1945, p. 15.

60
Experts conducting the studies included: Dr. Lynde P. Wheeler, Chief, FCC Technical Information Division; Armstrong; Philip Laeser, WTMJ, Milwaukee; Paul DeMars, consulting engineer, The Yankee Network: A. Earl Cullum, Jr., Radio Research Labs, Harvard; Dr. H.H. Beverage, RCA; D.B. Smith, Philco; Dr. Newburn Smith, National Bureau of Standards; George Davis, consulting engineer; and FCC engineers Edward W. Allen, George E. Sterling, George S. Turner, Virgil Sampson, and Curtis Plummer. See Broadcasting, May 25, 1945, p. 76.

61 "FM Decision Delayed as FCC Allocates," Broadcasting, May 21, 1945, p. 13.

62 "FCC Visions FM as Major Radio Service," Broadcasting, May 28, 1945, p. 17.

63 "Two-Band Sets Forbidden by FCC -- Porter Threatens to Cut Off Present Transmission If Manufacturers Defy Ban," New York Times, August 22, 1945, p. 30.

64 Introduced as evidence in 1948 House Hearings, pp. 154-158. See Appendix.

65 See House Hearings, p. 121.

66 "Industry Supporting Decision on FM Move," Broadcasting, July 9, 1945, p. 18.

67 Federal Communications Commission, Annual Report for 1949, (Washington, D.C.: U.S. Government Printing Office, 1950), p. 2.

68 Federal Communications Commission, Annual Report for 1950, (Washington, D.C.: U.S. Government Printing Office, 1951), p. 109.

69 Head, p. 179.

70 Lawrence Lessing, Man of High Fidelity: Edwin H. Armstrong (Philadelphia: J.B. Lippincott Company, 1956), p. 278. See also Lyons, p. 287.

71 Quoted in Lessing, p. 284. In support of this statement, see statement of Dr. Charles B. Jolliffe, RCA Vice-President, 1948 House Hearings, pp. 236-247.

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